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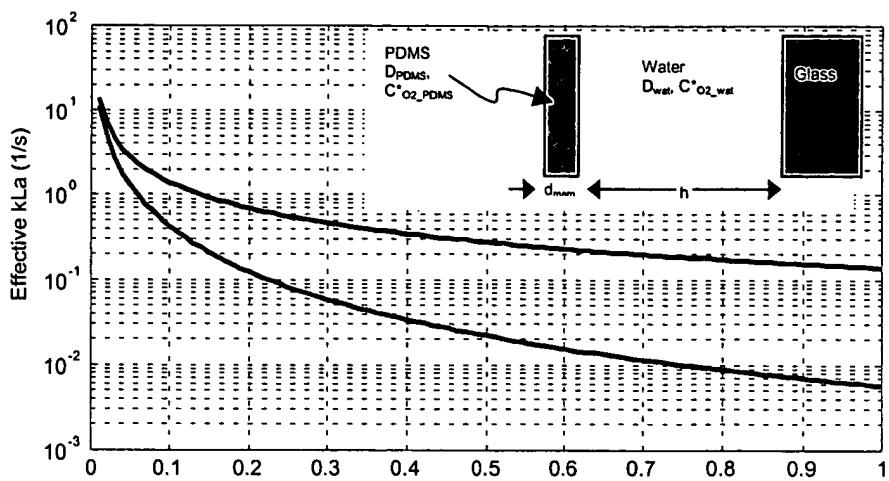
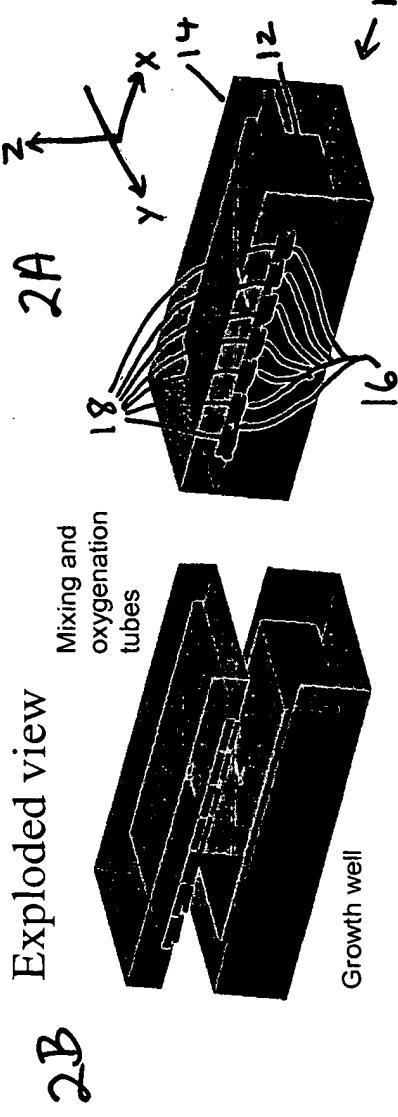


Figure 1

FIGURE 2



Actuation pattern (cross section view)

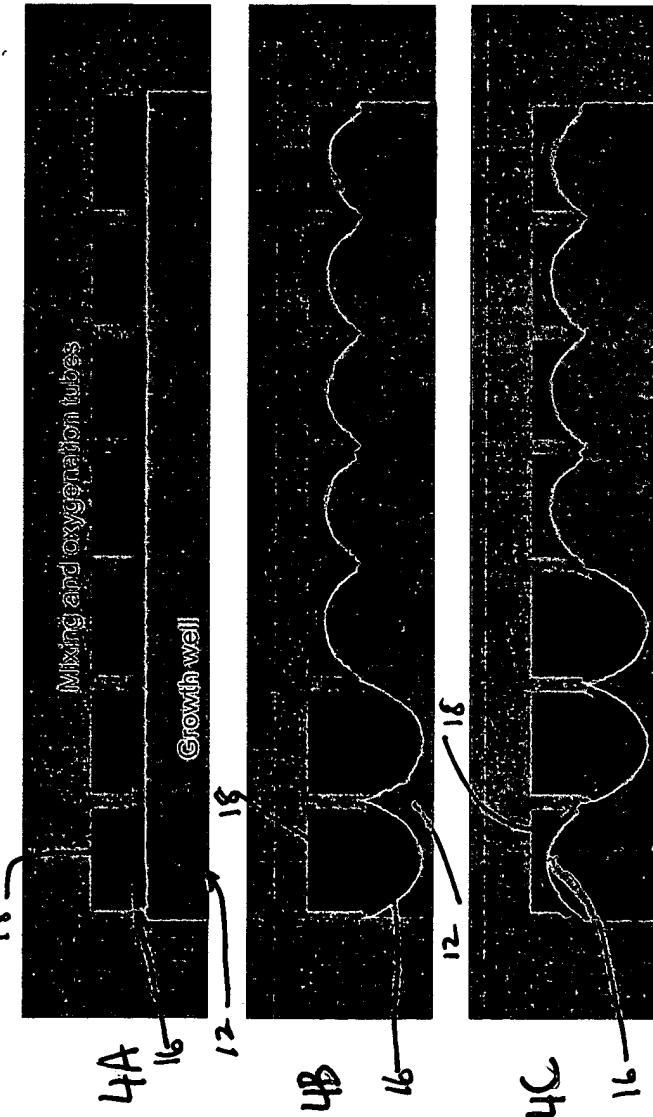
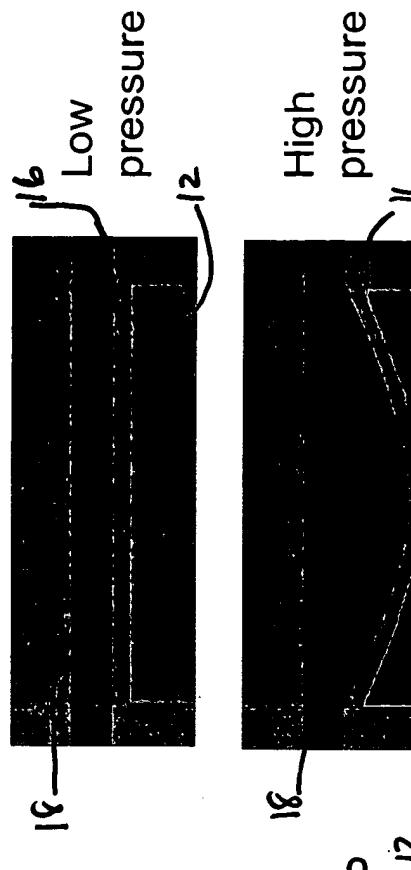
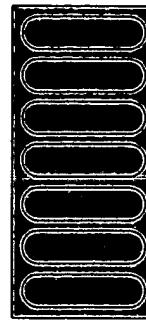


FIGURE 3

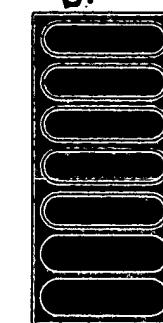
Tube profile (cross section view)



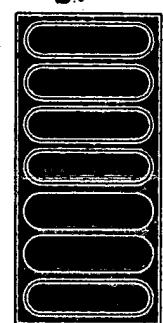
Top views (dark blue indicates pressurization), arrows indicate fluid flow



5A All tubes un-pressurized



5B Two left tubes pressurized, fluid is displaced to the right and up into the un-pressurized tubes.



5C Second tube stays pressurized, first tube is de-pressurized and third tube is pressurized. Fluid is pushed to the right by third tube and around second tube to push up first tube.

FIGURE 5

This pattern proceeds to the right and wraps around to the left when it reaches the right edge.
The next slide shows the entire pattern.

Approximate flow for straight tubes

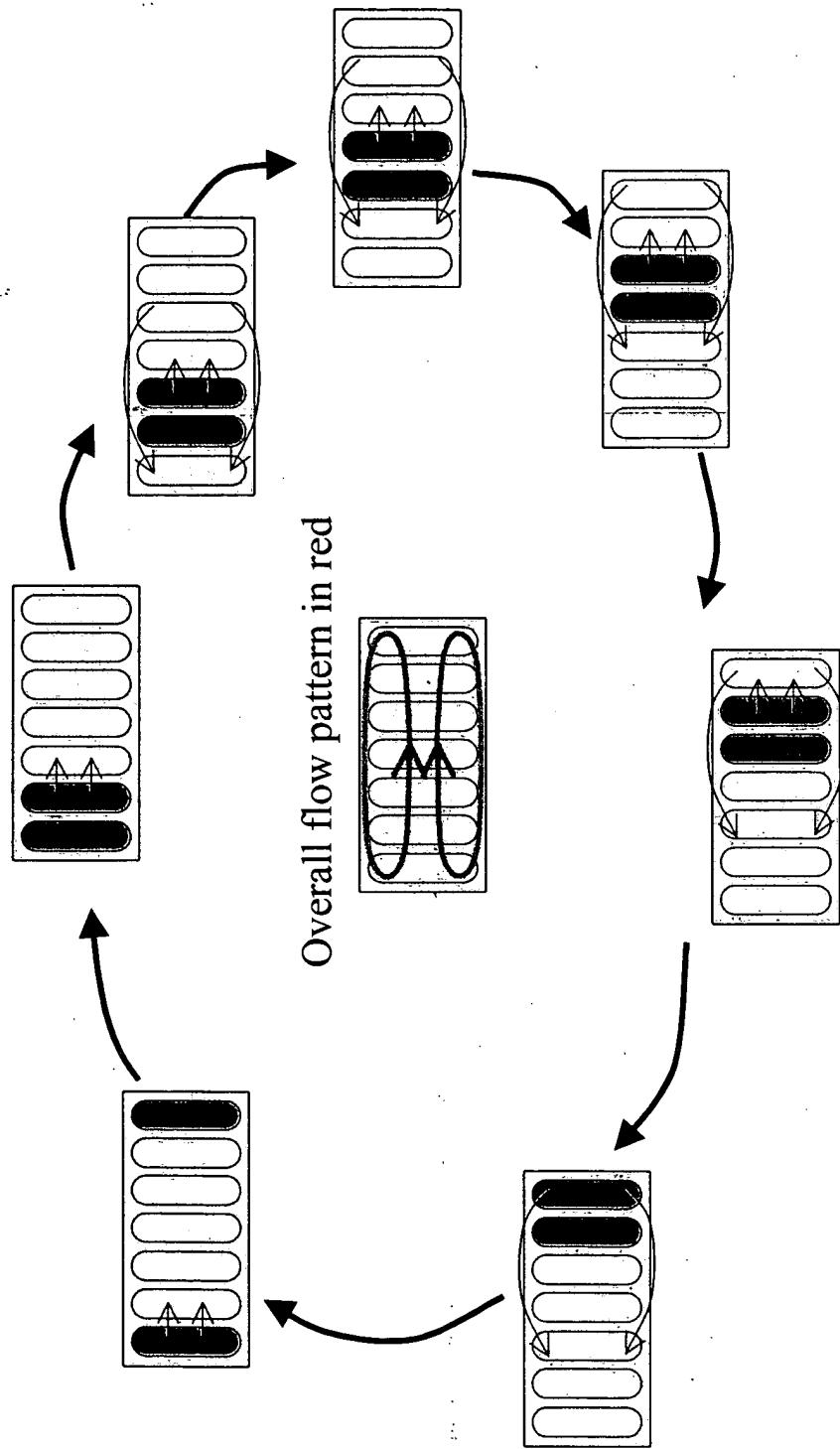


FIGURE 6

7 tubes and 3 valves, each color group is controllable.

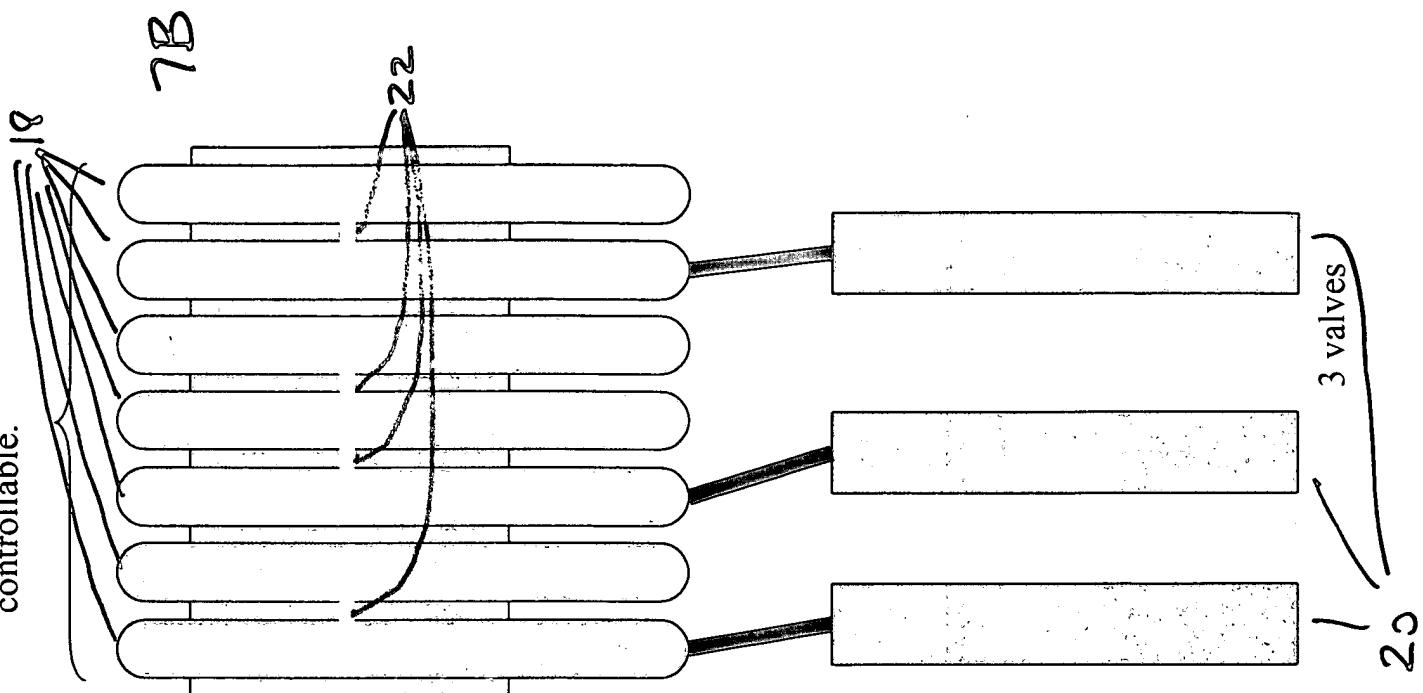


Figure 7

Left tube in each group is first to pressurize/depressurize, right tube last to pressurize/depressurize. Small connection between left/right tubes causes the delay (high flow resistance) Some flexibility is lost, but you can reduce the number of actuators.

7 tubes and 7 valves, each tube individually controllable

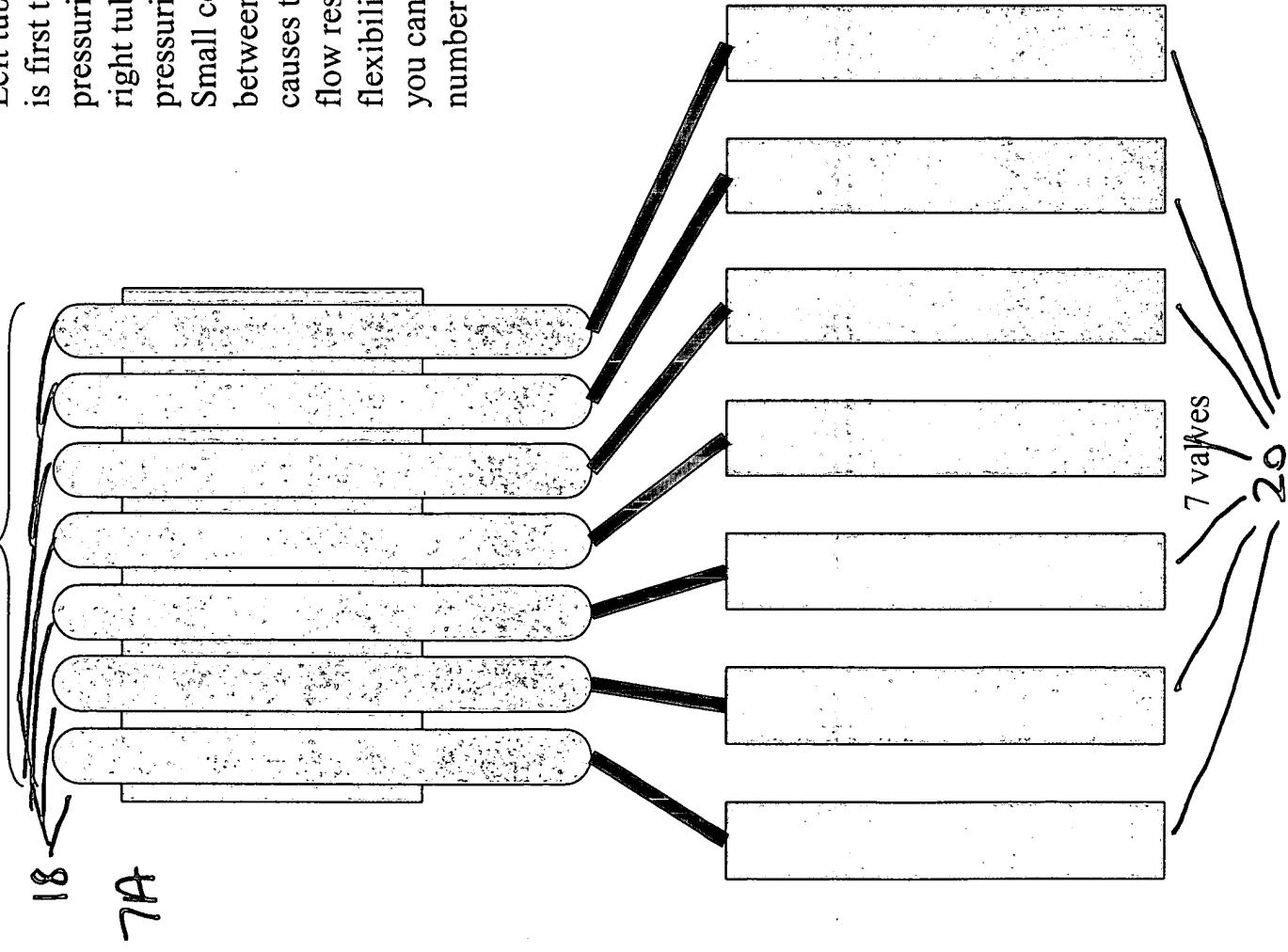


FIGURE 8

Approximate flow for wiggle (variable width tubes)

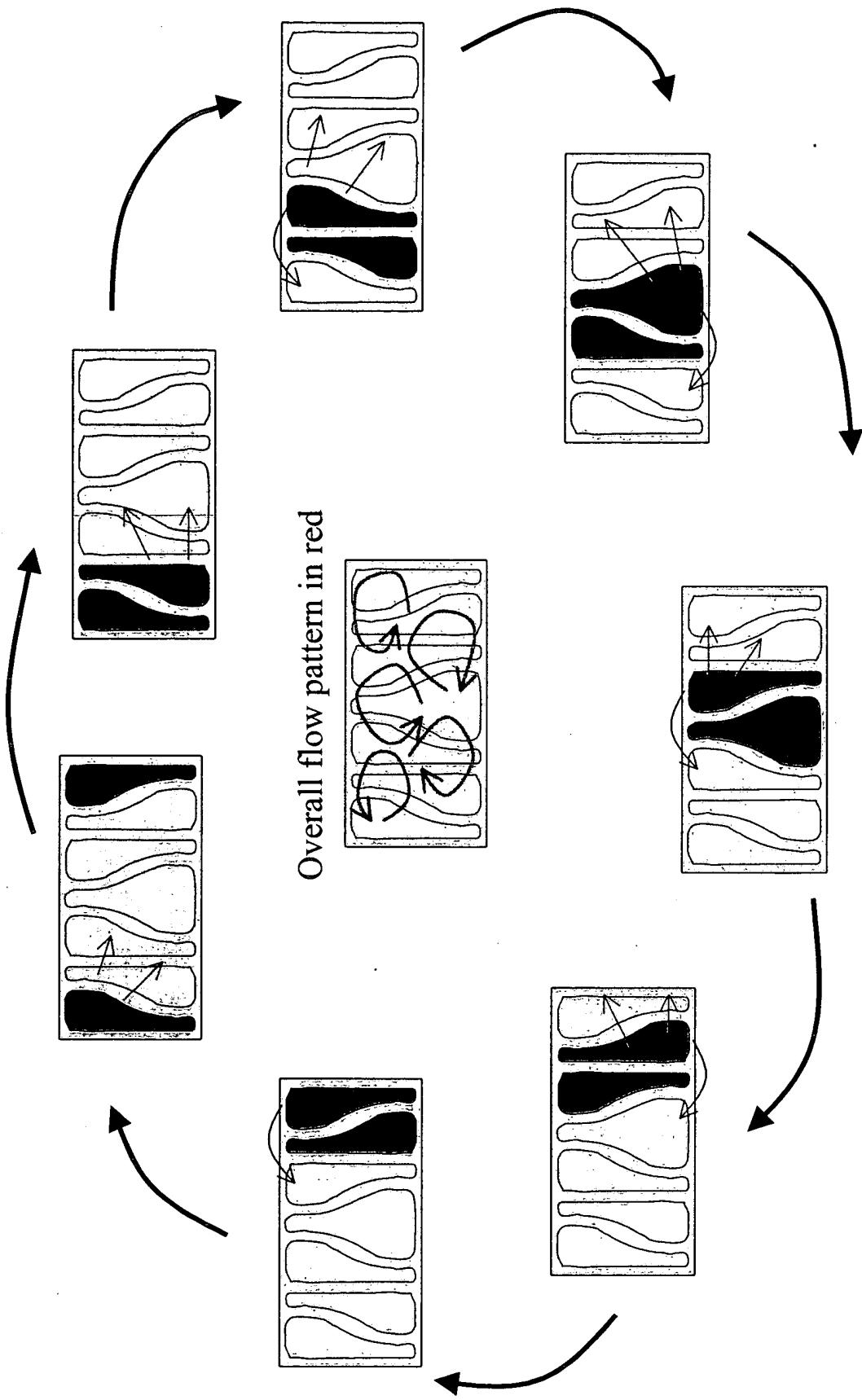
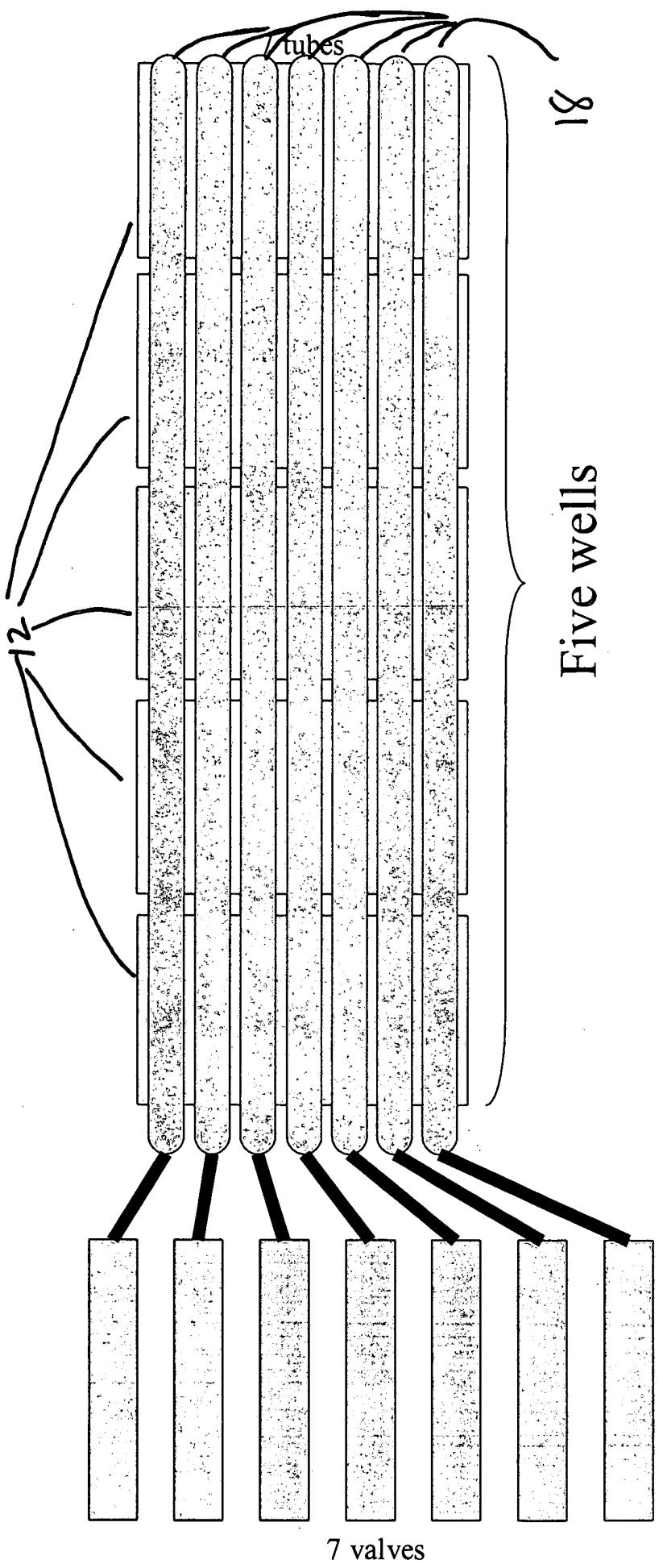


FIGURE 9A



7 individual high pressure lines (no communication, or small communication *between tubes* compared to flow rate out tube)

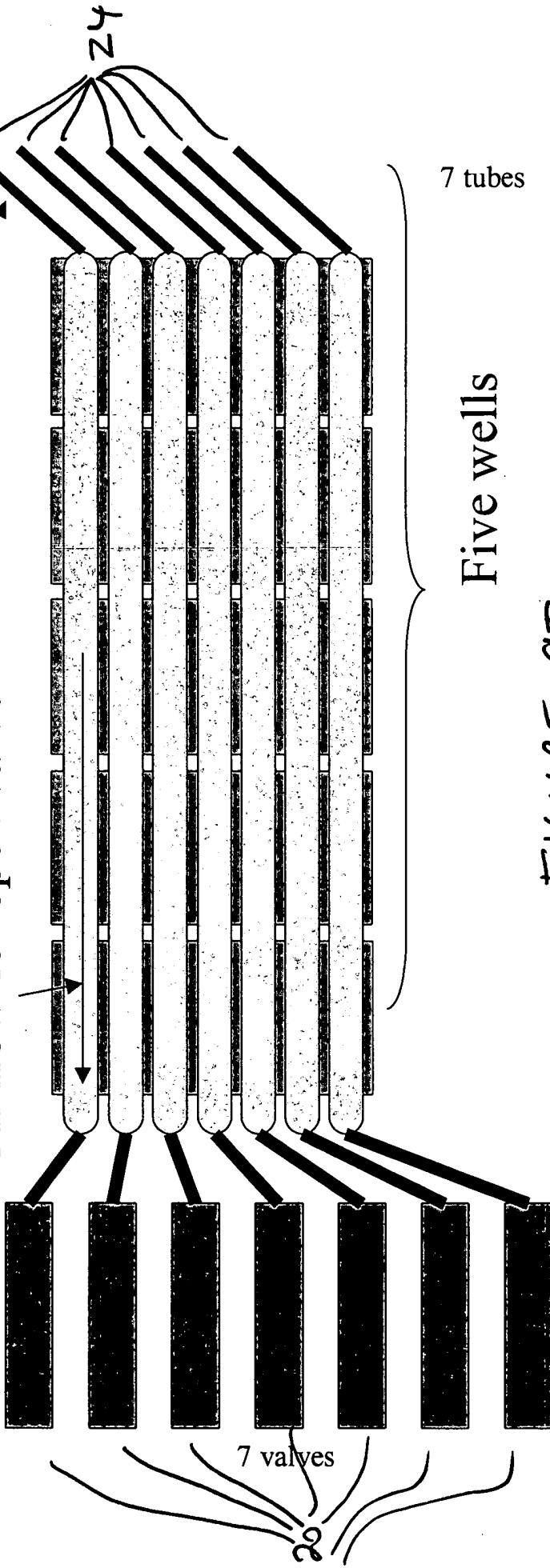


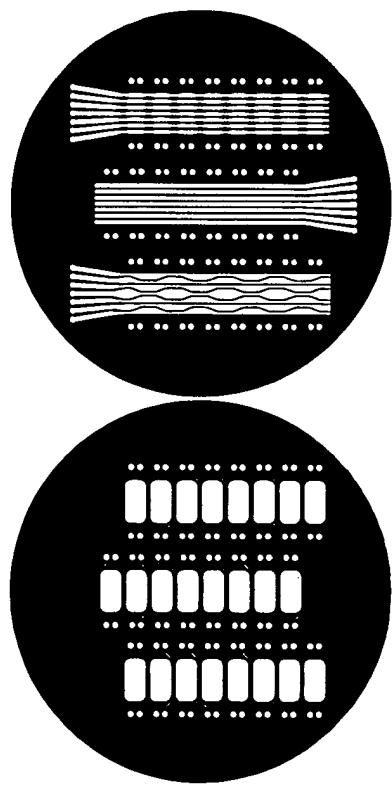
FIGURE 9B

7 individual valves open means air flows and tube is not pressurized. Closed means tube is pressurized to whatever the individual high pressure line pressure is.

Fabrication process

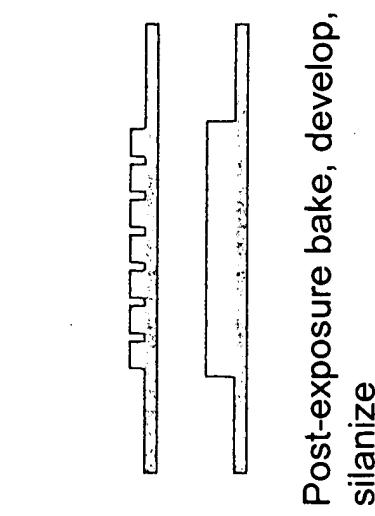
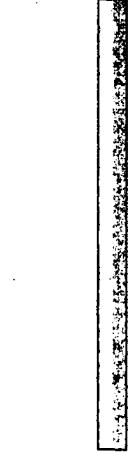
FIGURE 10

Make mold: SU-8
photolithography



A

Spin on SU-8,
pre-bake



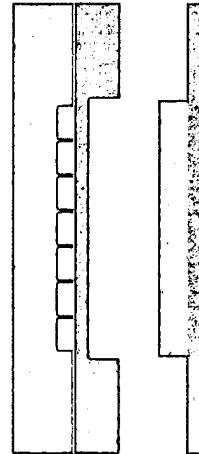
Post-exposure bake, develop,
silanize

Elastomer casting

50min 65°C 8:1



20min 65°C 20:1



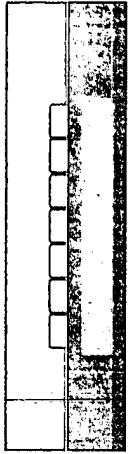
B

Expose with transparency mask

C

D

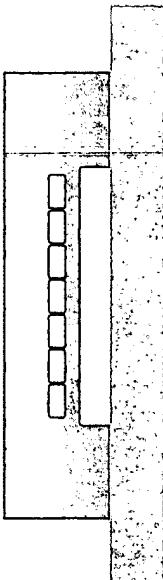
Full Cure 2 hrs
65°C



Align and seal

E

Bake ~2 hrs 65°C



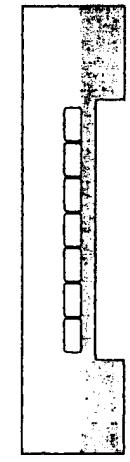
F

Seal to microscope slide

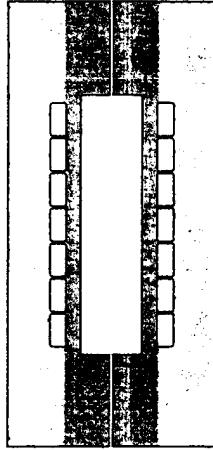
Cut out individual devices
and peel from mold

FIGURE 11

Another variation:

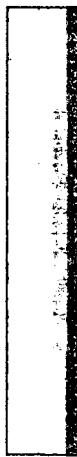


Cut out individual devices
and peel from mold



Seal two together back to
back for double sized
chamber.

Another embodiment



Same elastomer molded
tubes, or etched glass
tubes, or laser machined
tubes in plastic



Thin 100-300um thick
PDMS membrane spin on
and peel off

Conventionally machined
wells, or injection molded
wells, or epoxy molded
wells, or elastomer molded
wells.

FIGURE 12

FIGURE 13

This is the mask for the well, or chamber mold. The dashed circle is 3.5 inches in diameter and each well is 5mm x 10mm. The spacing between the wells is 1mm.

The dark areas on the mask will result in raised structures (typ: 300-500 μ m) on a silicon wafer substrate to form the mold. After casting the elastomer and peeling it off, the dark areas will be cavities in the silicone elastomer.

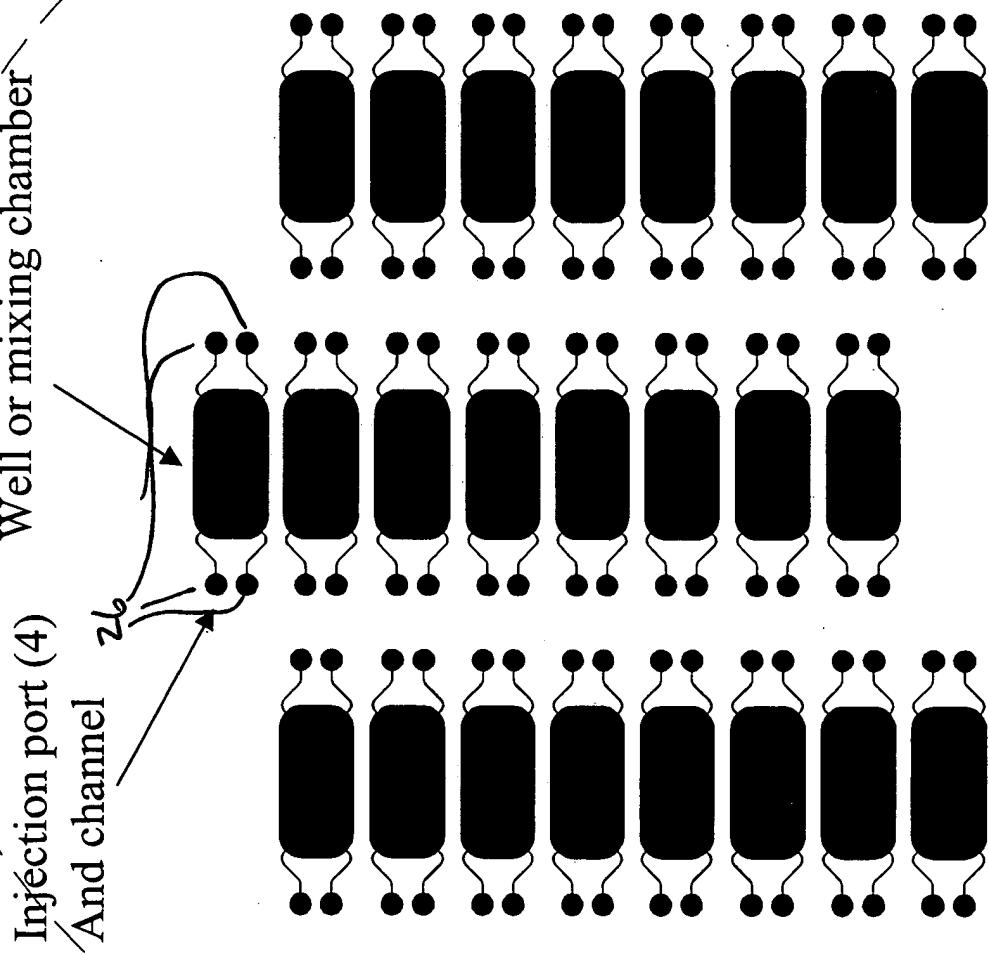


FIGURE 14

This is the mask for three different kinds of tubes. The left is the “wiggle tube” to drive flow transverse to the peristalsis direction. The middle is the standard straight tube, and the right are straight tubes with narrower regions near the edges of the wells. (The next slide shows the two masks overlayed)

The dark areas on the mask will result in raised structures (typ: 200-400 μm) on a silicon wafer substrate to form the mold. After casting the elastomer and peeling it off, the dark areas will be cavities in the silicone elastomer.

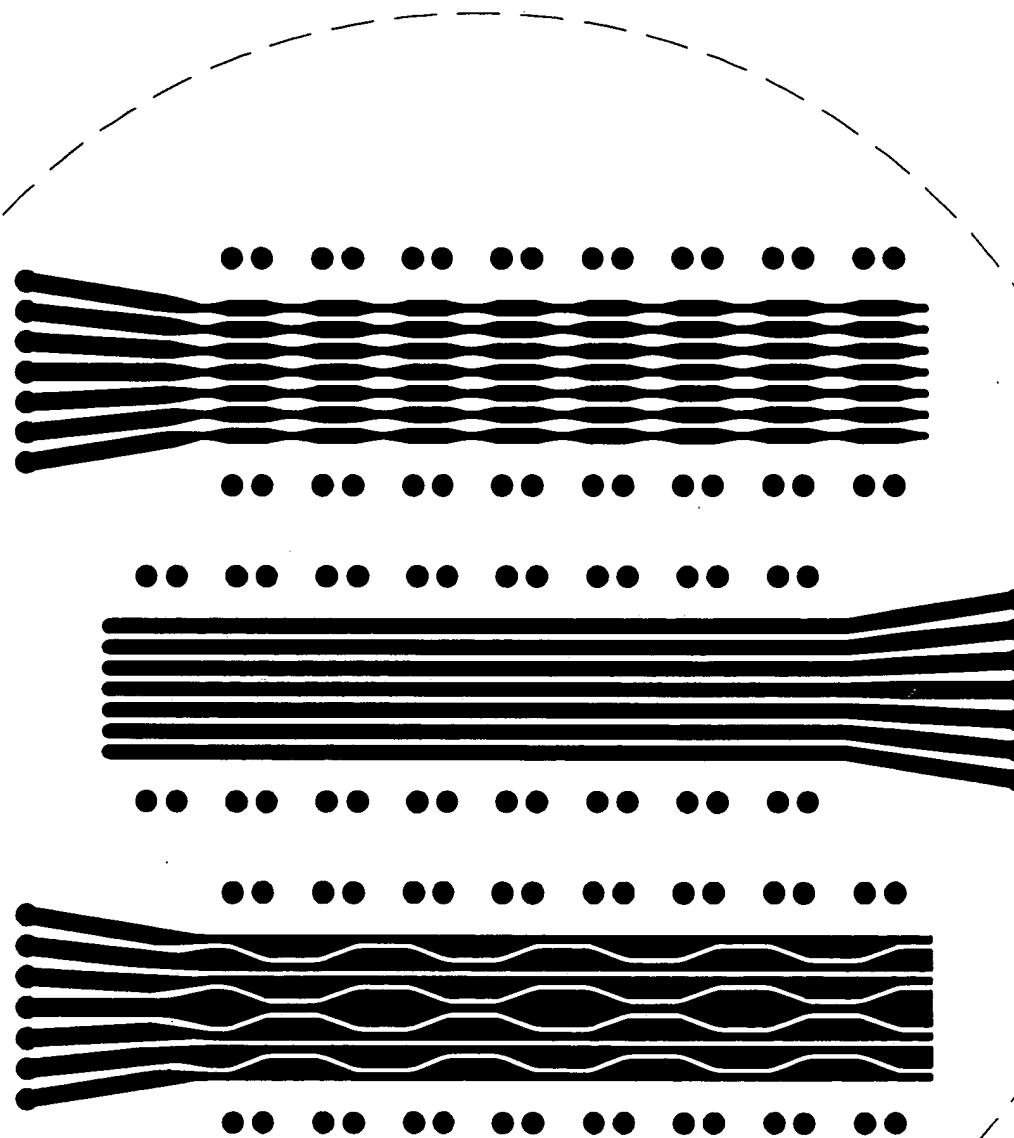


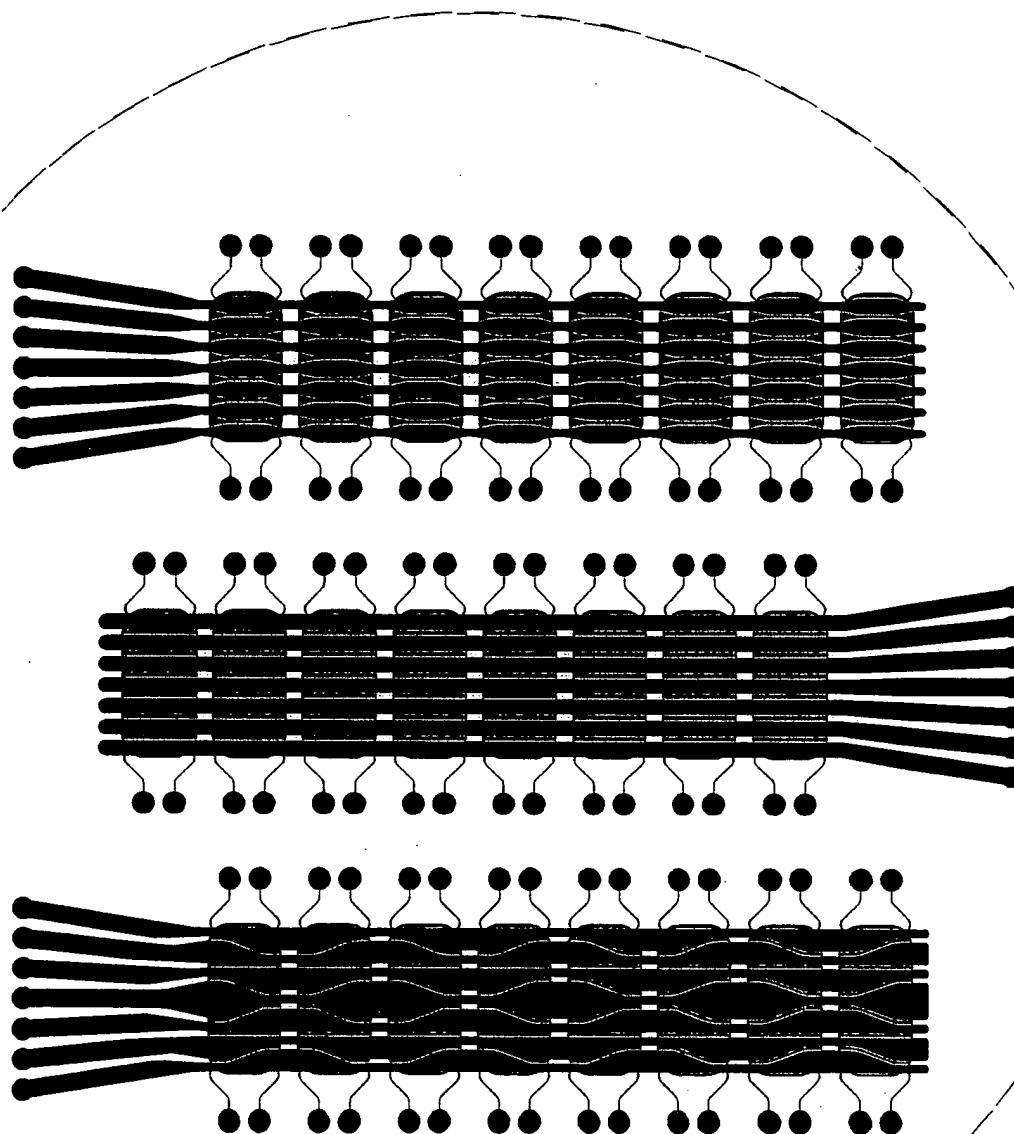
FIGURE 15

This shows the two masks
overlaid.

A key part of the design is the scalability. Note that only seven macroscopic actuators (Lee company solenoid valves – see later slide). Are required to actuate 8 wells because each tube crosses over eight wells. By making it longer, scalability would improve. (7 valves actuate 16, or 32 wells)

Current implementations are limited by the clean room processing tubes, and easy availability of 1x3 inch microscope slides substrates.

Minimizing the number of actuators is important to reduce overall system size and to keep to simplify the assembly of the macroscopic actuators.



The Lee Company www.theleeco.com LHDA valve

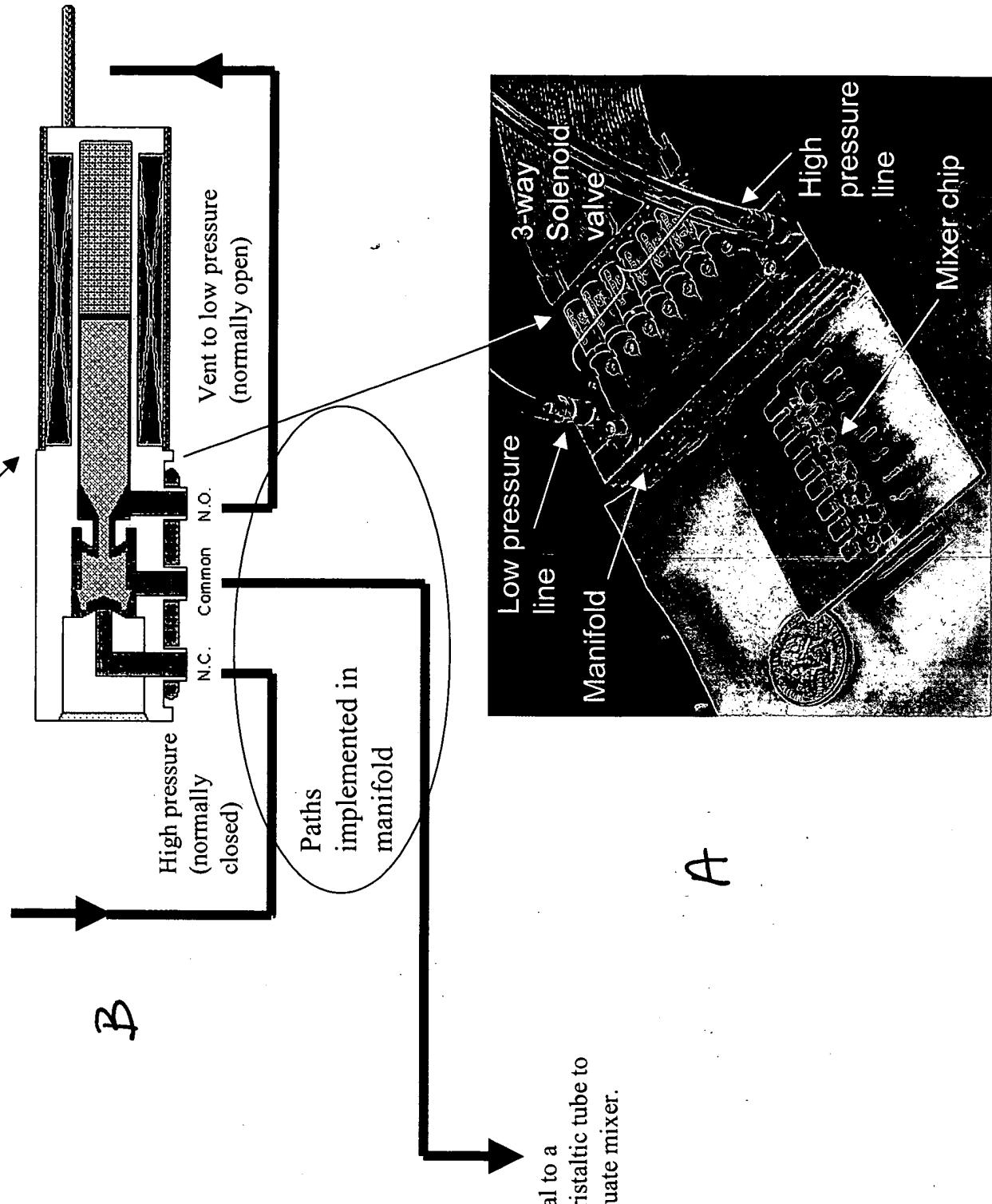


FIGURE 16

Exploded view of manifold, which mainly serves to reduce the pitch of the solenoid valves down to the pitch of the actuation ports.

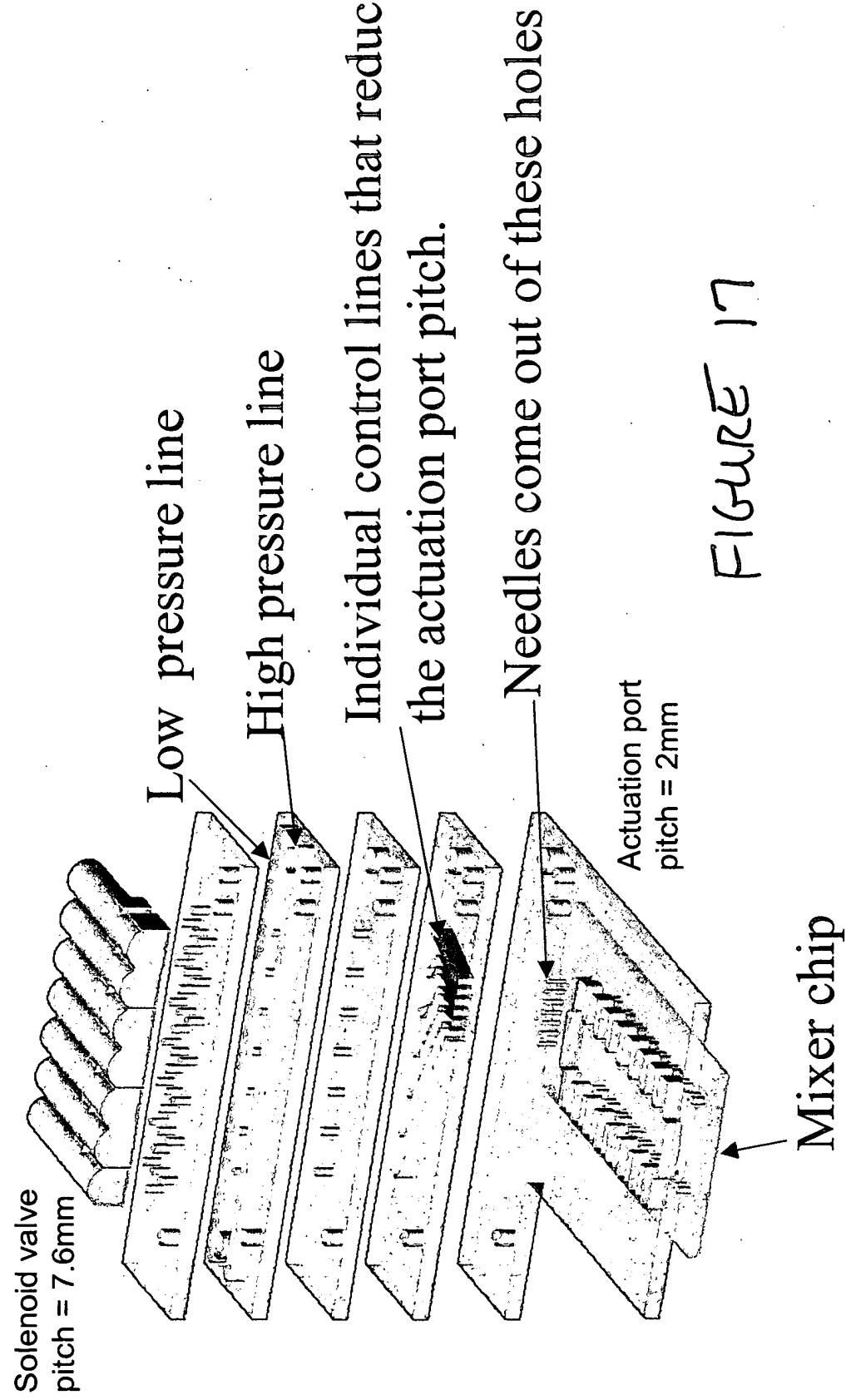


FIGURE 18

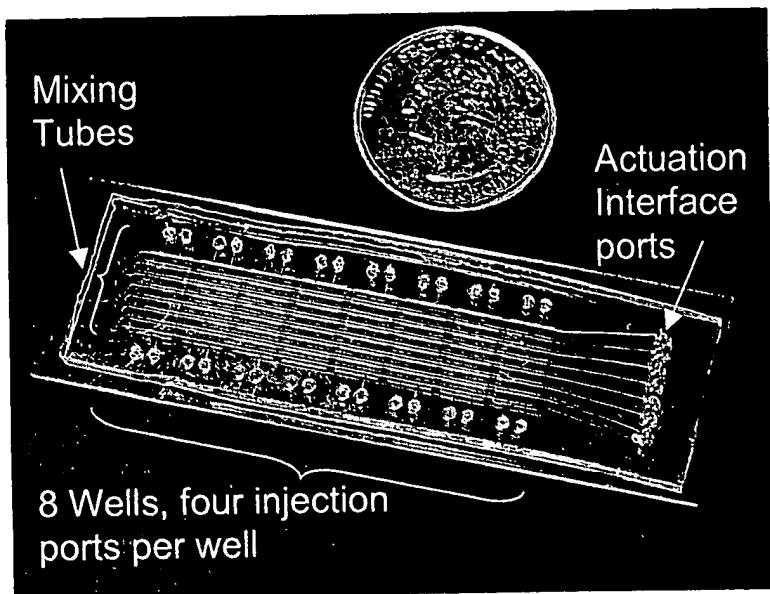


FIGURE 19

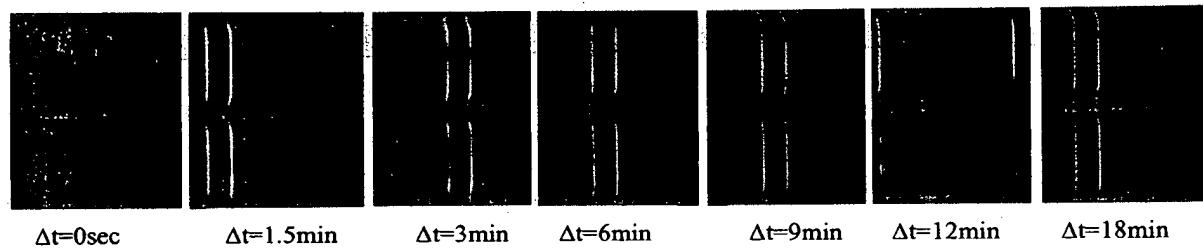
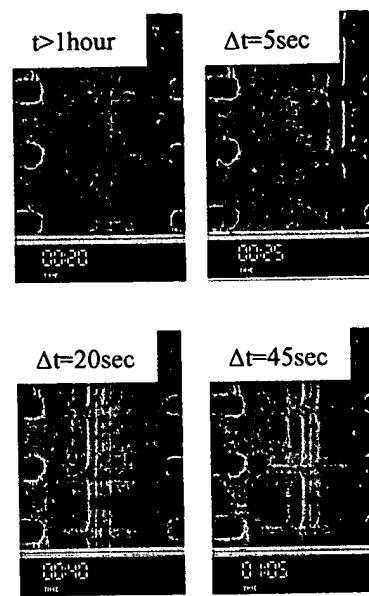
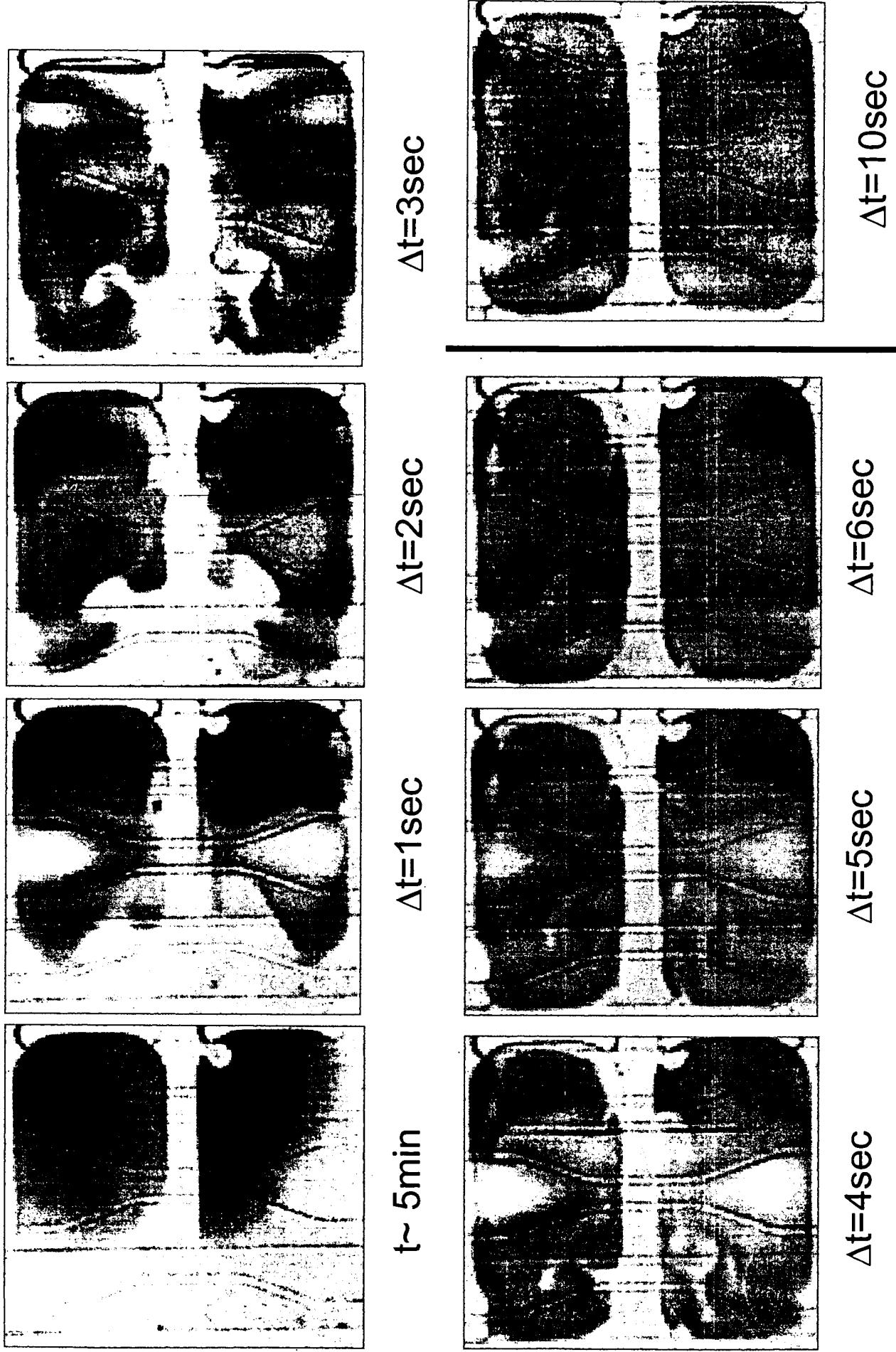


FIGURE 20

FIGURE 21



Note, the light areas look light because the tubes are deflected and the dye is pushed away, allowing more white background to show through. 8psi, 100Hz.

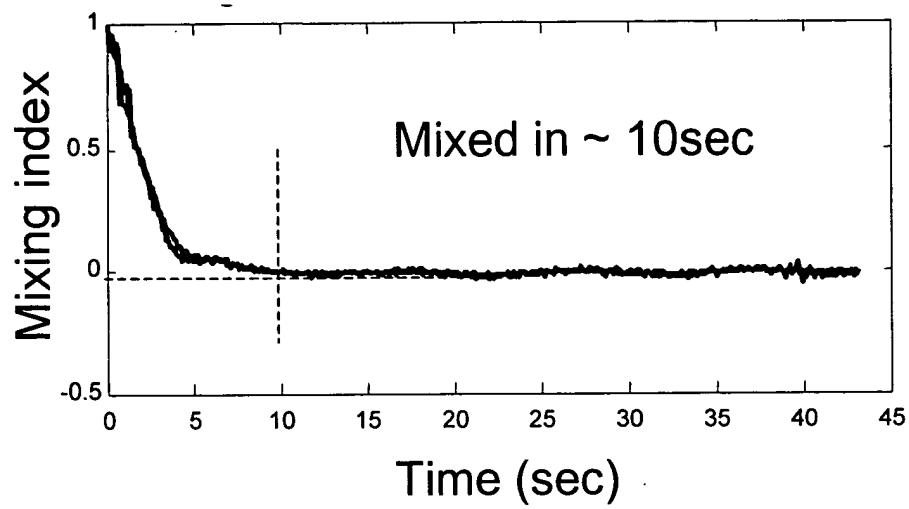
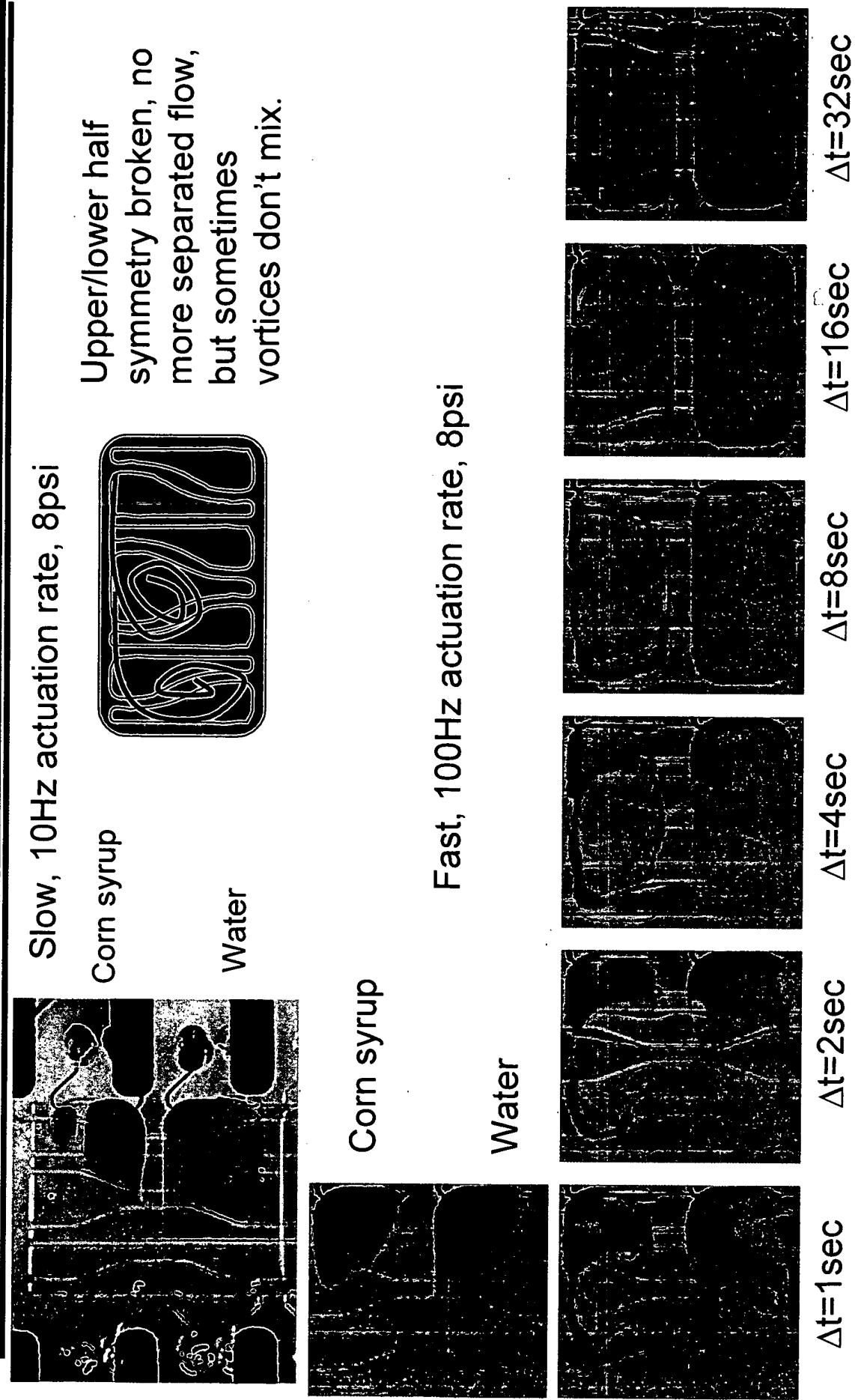


FIGURE 22

FIGURE 23

Mixing Results



Mixing trends

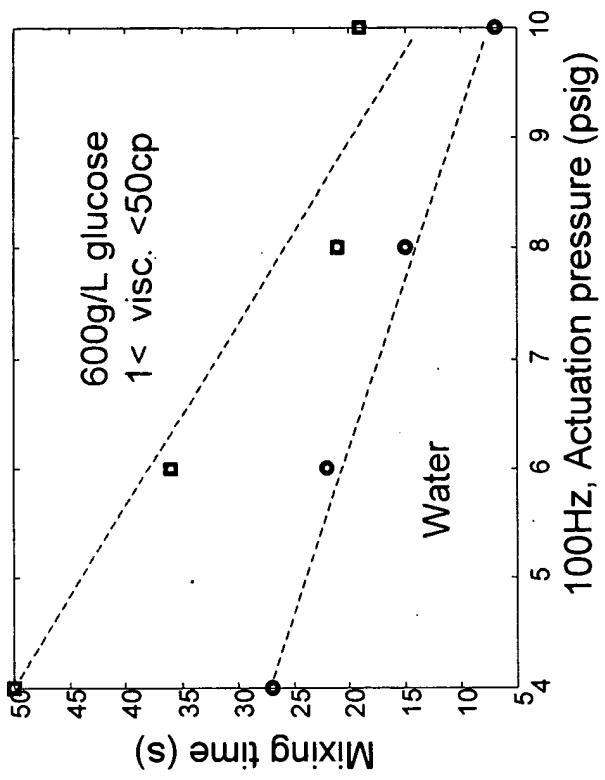
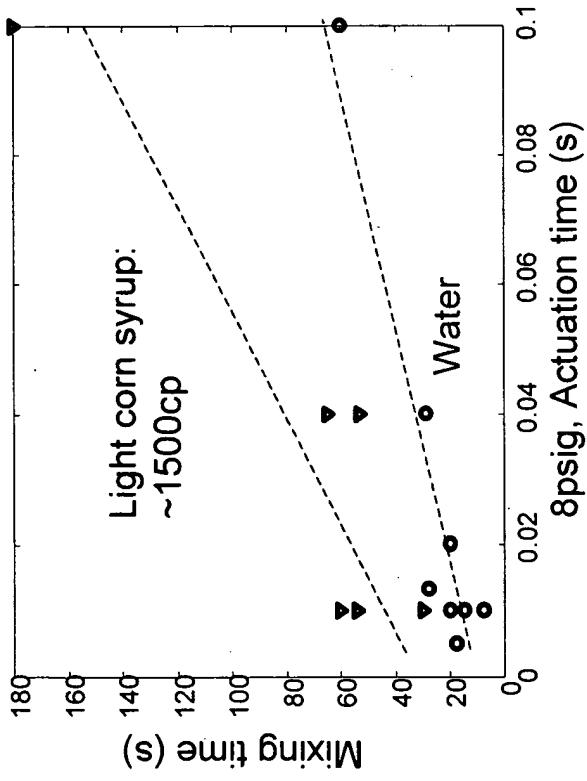


Figure 24